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STUDIES ON WESTERN AUSTRALIAN PERMIAN BRACHIOPODS
3. THE FAMILY LINOPRODUCTIDAE STEHLI 1954

By N. W. Archbold

Department of Geology, University of Melbourne, Parkville, Victoria 3052

Abstract: Representatives of the Linoproductidae (Productida, Brachiopoda) from the Western Australian Permian sequences are documented. Species are assigned to *Linoproductus*, *Cancrinella*, and *Lyonia* gen. nov. within the Linoproductinae and to *Globiella* within the Stepanoviellinae. The following species are revised or described: *Linoproductus* sp., *Cancrinella irwinensis* sp. nov., *Cancrinella bella* (Etheridge), *Cancrinella coolkilyaensis* sp. nov., *Cancrinella* sp. A, *Cancrinella* sp. B, *Lyonia lyoni* (Prendergast), *Globiella umariensis* (Reed), *Globiella foordi* (Etheridge), *Globiella flexuosa* (Waterhouse). The classification of the family Linoproductidae is briefly discussed and the Proboscidellinae of Muir-Wood and Cooper is raised to family status as the Proboscidellidae.

This paper reviews and describes all known Western Australian Permian species of the Linoproductidae. Representatives of *Cancrinella* and *Globiella* are particularly abundant at certain stratigraphical levels and are useful for intrabasinal correlations.

COLLECTIONS AND TERMINOLOGY

Figured and measured specimens are housed in the institutions indicated by the following prefixes to registered numbers. CPC—Commonwealth Palaeontological Collections of the Bureau of Mineral Resources, Geology and Geophysics, Canberra; GSWA—Geological Survey of Western Australia, Perth; AMF—Australian Museum, Sydney; MUGD—Department of Geology, University of Melbourne; UWA—Department of Geology, University of Western Australia, Perth. The terminology used herein follows Muir-Wood (1965) and Sarycheva (1970).

STRATIGRAPHY AND AGE

Marine Permian sedimentary sequences in the Perth, Carnarvon and Canning Basins each contain Linoproductidae; their biostratigraphy and lithostratigraphy have been alluded to previously (Archbold, 1981, 1982a).

SYSTEMATIC PALAEONTOLOGY

Order Productida Sarycheva & Sokolskaya 1959

Suborder Productidina Waagen 1883

Superfamily Linoproductacea Stehli 1954

Family Linoproductidae Stehli 1954

Diagnosis: Normally costellate Linoproductacea, rarely rugose, row of fine spines near hinge, cardinal process trilobate, small body cavity, dendritic, striate or smooth ventral adductor scars.

Discussion: The classification of the Linoproductacea presented by Waterhouse (1978a), is provisionally accepted with minor modification. Wang *et al.* (1966) anticipated several of the modifications suggested by Waterhouse (1978a) and 1 formally raise the Proboscidellinae Muir-Wood & Cooper 1960 to the family Proboscidellidae. The family is characterised by the distinctive morphology of the ventral valve and the bilobate cardinal process of the two included genera: *Proboscidella* Oehlert 1887 and *Siphonosia* Cooper & Grant 1975. As in Waterhouse (1978a), the Gigantoproductidae are provisionally included within the Linoproductacea because genera such as *Linoprotonia* Ferguson 1971 and species groups such as the *Gigantoproductus maximus* group (Pattison 1981) appear to be linoproductaccan in affinity. The Linoproductidae is restricted to include the Linoproductinae, Stepanoviellinae and the Yakovleviinae. The latter, which includes *Yakovlevia* Fredericks (1925) and *Duartia* Mendes (1959) is retained within the Linoproductidae in view of their trilobate cardinal process and finely costellate ornament.

Subfamily Linoproductinae Stehli 1954

Diagonsis: Linoproductidae with dendritic or striate ventral adductor scars, wide hinge and trail usually long.

Genera Included and Discussion: The following genera are included in the subfamily: *Linoproductus* Chao 1927, *Cancrinella* Fredericks 1928, *Terrakea* Booker 1930, *Marginirugus* Sutton 1938, *Haydenella* Reed 1944 (see Grant, 1976), *Fluctuaria* Muir-Wood & Cooper 1960, *Ovatia* Muir-Wood & Cooper 1960, *Grandaurispina* Muir-Wood & Cooper 1960, *Balakhonia* Sarycheva 1963, *Asperlinus* Waterhouse & Piyasin 1970, *Striatospica* Waterhouse 1975, *Auriculispina* Waterhouse 1975, *Vitiliproductus* Ching & Liao 1974, *Magadania* Ganelin 1977 (in Grigor'eva *et al.* 1977), *Kasetia* Waterhouse 1981 and *Lyonia* gen. nov. The genera *Holotricharina* Cooper & Grant 1975 and *Undellaria* Cooper & Grant 1975, included by those authors in Linoproductinae, are only provisionally retained within the subfamily. Both Texan genera are characterised by a non-costellate external ornament and hence are not "conventional" Linoproductinae.

Discussion of *Haydenella* Reed by Grant (1976) indicates a firm linoproductinid affinity for the genus contrary to the view of Jing and Hu (1978), who also synonymised *Chianella* Waterhouse (1975) with *Haydenella* Reed (1944).

Auriculispina Waterhouse (1975), type species *Cancrinella levis* Maxwell (1964) from the Asselian Burnett Formation, Yarrol Basin, Queensland, requires further investigation (Waterhouse 1976a); the genus is assigned provisionally to the Linoproductinae.

Genus **Linoproductus** Chao 1927
(= *Cora* Fredericks 1928; = *Euproductus* Whitehouse 1928)

TYPE SPECIES: *Productus cora* d'Orbigny 1842.

DIAGNOSIS: The diagnosis provided by Muir-Wood and Cooper (1960) is used herein.

Linoproductus sp.
Fig. 1A, B

MATERIAL: One internal mould of a ventral valve, GSWA11192, from GSWA locality 30111. Mt. Phillips (1972) run 6/1212, pt. 1117 RMH, BK5, Lyons Group, Yard Grid 360-937 of Tastubian (Early Sakmarian) age.

DESCRIPTION: Specimen transversely oval in outline. Ventral valve unevenly convex with posterior strongly curved and anterior of valve gently curved. Ventral umbo small, pointed. Rugae distinctly developed on ears and extremities of lateral slopes but not crossing venter. Surface finely costellate, with 27 costellae per cm at 1.5 cm from umbo and 16 costellae per cm at 3 cm from umbo. Anterior of valve turned into trail.

DISCUSSION: The fine costellae, some bifurcating, others arising from intercalation, the arrangement of the rugae and the large size (height = 34 mm; maximum width = 44 mm) suggest a species of *Linoproductus*. The specimen is differentiated from *Globiella* by its finer costae and the convexity of the ventral valve. Material is inadequate for comparison with other species of the genus but this specimen appears to be the only *Linoproductus* known from the Permian of Australia.

Genus **Cancrinella** Fredericks 1928

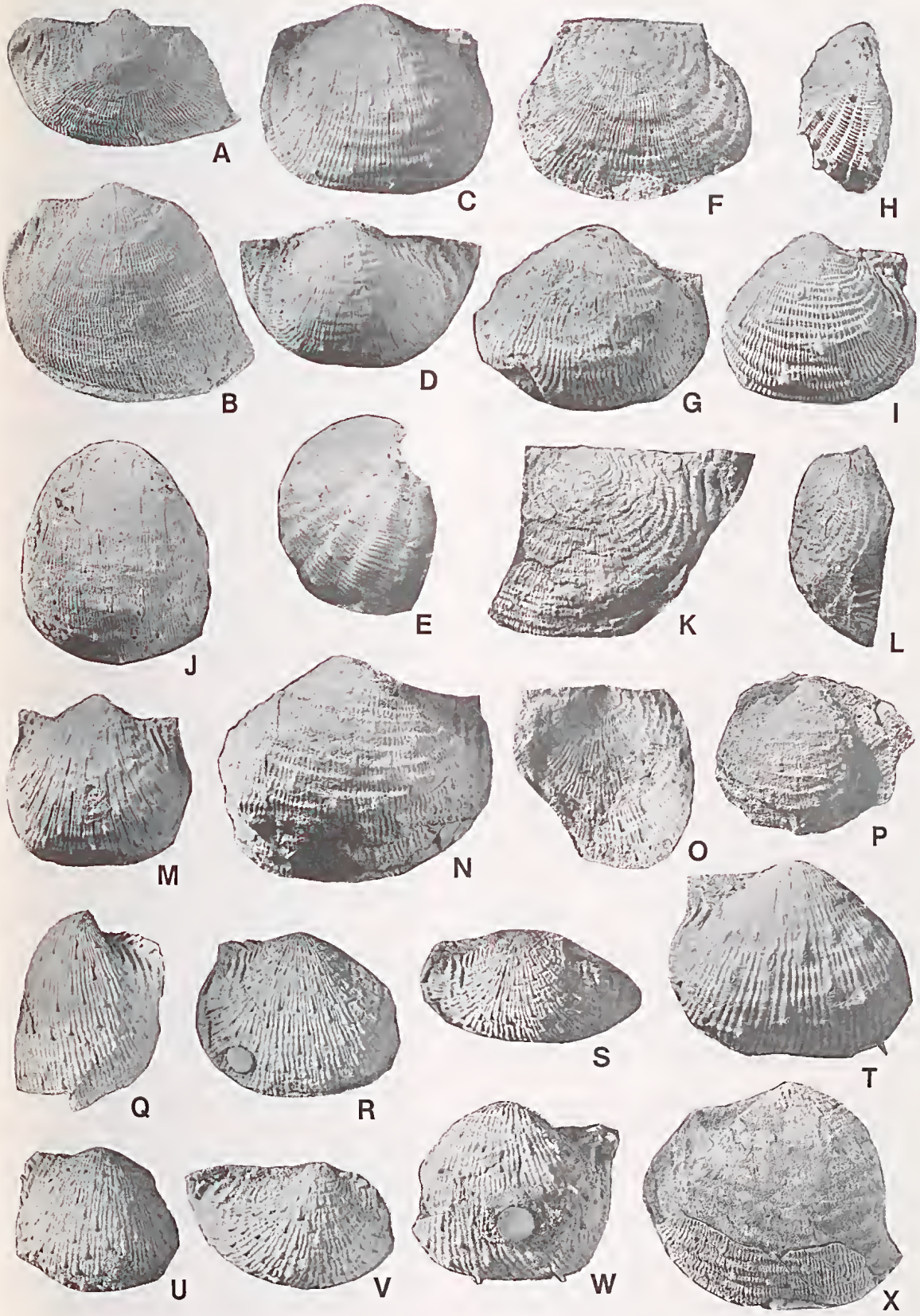
TYPE SPECIES: *Productus cancrini* de Verneuil 1845. = *Productus cancrini* de Verneuil 1842 (in de Koninck 1842).

DIAGNOSIS: Small to medium, thin shelled Linoproductinae with small, flattened ears and strongly incurved umbo. Ventral valve with fine costellae and numerous long fine spines arising from costellae at a low angle; tuft of halteroid spines developed on ears. Dorsal valve costellate and rugose, dimpled with no spines. Ventral valve with rugae—at times only on ears.

DISCUSSION: Hill (1950) and Muir-Wood and Cooper (1960) discussed the early usage of *Productus cancrini*—first by de Koninck (1842) who figured a Lower Carboniferous shell, then by de Verneuil and Murchison (1844) in a list of Permian fossils of Europe and finally, in a restricted sense, by de Verneuil (1845, in, Murchison *et al.*, 1845) for the Permian shells; the Carboniferous shells of de Koninck were transferred to *Productus koninckianus* de Verneuil (1845 in Murchison *et al.* 1845). I follow Cooper and Grant (1975) and Grigor'eva *et al.* (1977) and regard the type species of *Cancrinella* as being *Productus cancrini* de Verneuil (1845). As noted by Hill (1950, p. 12), de Verneuil (1845) in effect chose de Koninck's (1842) Russian Zechstein specimen as the lectotype when he renamed the Viséan specimens *P. koninckianus*. This stabilised the character and horizon of *P. cancrini*, if not the author, but Fredericks (1928) chose *P. cancrini* de Verneuil (1845) as the type species of his genus. To stabilise authorship of *P. cancrini*, Fredericks's choice should be regarded as being a clear indication that he intended the Permian species to be type. De Koninck (1842), Table opposite p. 154) stated that de Verneuil was the author of *Productus cancrini* although on page 180 he attributed the name to both de Verneuil and von Keyserling. As a result 1842 could justifiably be given as the date of de Verneuil's species.

Grigor'eva *et al.* (1977) recognised two species groups within *Cancrinella*, namely the group of *C. cancrini* (de Verneuil) and the group of *C. cancriniformis* (Tschernyschew 1889). *Cancrinella cancrini* (de Verneuil) is a variable species (Grigor'eva *et al.* 1977, pl. 19, figs 1-9) lacking rugae on the ventral valve, except on the small ears, and possessing well spaced spines which are relatively coarse as in other species assigned to the group. The group of *C. cancriniformis* possesses distinct rugae across the ventral valve and strongly developed rugae on the ears. Spines in this group may be finer and more regularly spaced. The two groups are not mutually exclusive. *Cancrinella bella* (Etheridge 1918), is an intermediate, and it appears unwise to formalise the two groups. Large species attributed to *Cancrinella* (e.g. *C. grandis* Solomina 1981) that possess dorsal valve spines are not true representatives of the genus and are not morphologically close to the species described below nor to *C. cancrini* and its allies from European Russia. Such species may be better referred to either *Filiconcha* Dear 1969 or *Cancrinelloides* Ustritskiy (in Ustritsky & Chernyak 1963)—both genera apparently being allied to the Monticuliferidae (see Waterhouse 1976a).

Fig. 1—A-B, *Linoproductus* sp.; from Lyons Group, Carnarvon Basin, A-B, GSWA11192, ventral valve internal mould in posterior and ventral views, ×1. C-P, *Cancrinella irwensis* sp. nov.; C-G, J, M from Fossil Cliff Member, Perth Basin; H-I, K-L, N-O, from Callytharra Formation, Carnarvon Basin, P, from Cuncudgerie Sandstone, Canning Basin. C-E, Holotype, CPC19915A, ventral valve internal mould in ventral posterior and lateral views, ×1.3, ×1.5 and ×1.3 respectively. F, CPC19915I, dorsal valve external mould, ×1.5. G, CPC19915F, ventral valve internal mould in ventral view, ×1.5. H-I, MUGDF6027, ventral valve in lateral and ventral views, ×1.5. J, CPC19915B, ventral valve internal mould in ventral view, ×1. K-L, CPC19917C, dorsal valve in ventral and lateral views, ×1.2. M, CPC19915G, ventral valve internal mould in ventral view, ×1.4. N, CPC19917B, ventral valve in ventral view, ×1.2. O, CPC19917F, dorsal valve in dorsal view, ×1.5. P, CPC19918, natural cast of ventral valve in ventral view, ×1.3. Q-X, *Cancrinella bella* (Etheridge); Q-S, U-X, from Noonkanbah Formation, Canning Basin; T, from Wandagee Formation, Carnarvon Basin. Q, AMF16812, ventral valve in ventral view, ×1.3. R-S, AMF16731, ventral valve in ventral and posterior views, ×1.3. T, MUGDF6028, ventral valve in ventral view, ×1.8. U-V, AMF16734, ventral valve in ventral and posterior views, ×1.3 and ×1.5 respectively. W, AMF16742, lectotype, ventral valve in ventral view, ×1.3. X, CPC19919, ventral valve in ventral view, ×1.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Cancrinella irwinensis sp. nov.
Fig. 1C-P

1890 *Productus undatus*: Foord. *Geol. Mag. Dec.*, 3(7): 152, pl. 7, fig. 6.
1907 *productus undatus*: Etheridge. *Bull. geol. Surv. W. Aust.*, 27: 30.
1910 *Productus undatus*: Glauert. *Bull. geol. Surv. W. Aust.*, 36: 87.
1926 *Productus bellus*: Glauert (*partim.*) *Bull. geol. Surv. W. Aust.*, 88: 46.
1931 *Productus undatus*: Hosking. *J. roy. Soc. W. Aust.*, 17: 8, 22.
1935 *Linoproductus cancriniformis*: Prendergast (*partim.*), p. 14, pl. 2, figs 7-10. *non. cet.*).
1943 *Linoproductus cancriniformis*: Prendergast (*partim.*), p. 23.
1957 *Linoproductus cancriniformis*: Coleman (*partim.*), p. 69.
1957 *Linoproductus lyoni*: Coleman (*partim.*), p. 76.

Etymology: From the Irwin River, Perth Basin, Western Australia.

Holotype: CPC19915A, a ventral valve internal mould from BMR Locality IR20, Fossil Cliff Member, Perth Basin.

Material and Localities: CPC19915A-199151, 8 ventral valve internal moulds and 1 dorsal valve external mould from BMR locality IR20, Carynginia Gully, 2.8 km on a bearing of 297° from Carynginia Well, Fossil Cliff Member; CPC19916A-19916C, 2 ventral valve internal moulds and 1 dorsal valve external mould from BMR locality PB7, 0.8 km on a bearing of 334° from Carynginia (No. 1) Well, Irwin River Area, Fossil Cliff Member, Perth Basin; CPC19917A-19917F, 4 ventral valves and 2 dorsal valves from BMR locality 7044/0116, Minilya Run 13A Photo 5043, JMD Pt. 1, middle part of Callytharra Formation; MUGDF6027, a ventral valve from G. A. Thomas locality P491, 33 m above base of type section of Callytharra Formation, Callytharra Springs, Carnarvon Basin; CPC19918, natural cast of ventral valve from BMR locality T0127, Scott Bluff, Lake Blanche, 22°31′06″S, 124°14′16″E, Cuncudgerie Sandstone, Canning Basin.

Diagnosis: Medium to large sized *Cancrinella*. Normally with strongly convex ventral valve. Strongly, but finely, rugose and costellate shell with fine spines on ventral valve. Dorsal valve relatively weakly geniculate.

Table 1
Size ranges of populations of *Cancrinella irwinensis* sp. nov. (in mm)

Stratigraphic horizon	Maximum width	Hinge width	Ventral length	Dorsal length	Thickness
Fossil Cliff	18.0-32.0	14.2-22.5	15.5-33.1	17.7	8.8-19.2
Callytharra	18.5-39.0	18.2-38.0	16.1-29.0	14.0-28.0	13.8-14.5
Cuncudgerie	17.3	–	18.0	–	–

Description: Medium to large for genus, subquadrate to elongate outline. Maximum width slightly greater than hinge width. Shell surface marked by distinct, fine rugae and costellae. Rugae strongest on ears and lateral slopes, distinct but low across venter and trail. Costellae rounded with narrow interspaces, number about 2 to 3 per mm at 1.5 cm from ventral umbo. Rugae number 12+ in first cm of growth and about 6 in second cm of growth. Spines arranged in tufts on ears, body spines arise from end of elongate swollen costellae, extend anteriorly at a low angle to shell surface. Dorsal valve with costellae, fine rugae and elongate dimples.

Profile of ventral valve strongly convex, trail slightly less curved than posterior of valve. Ventral umbo small, overhangs dorsal umbo. Ears distinct, square in outline.

Dorsal valve gently concave in region of visceral disc, relatively weakly geniculate on trail. Trail at about 20°-50° to plane of visceral disc (see also Prendergast 1935, pl. 2, fig. 7).

Ventral interior may carry extensive elongate narrow ridges (specimen CPC19915G, Fig. 1M) over entire visceral disc. Dorsal interior poorly known; small cardinal process and distinct median septum present.

Discussion: Coleman's (1957) three examples of *Linoproductus lyoni* from the Callytharra Formation were examined and found to be variably preserved specimens of the new species.

Rare specimens from the Callytharra Formation with the characteristic ornament of the species indicate a maximum width probably in excess of 50 mm. They are invariably distorted and crushed but appear to be somewhat less convex than smaller specimens.

C. irwinensis belongs to the *C. cancriniformis* group with distinct rugae across the venter of the shell. *C. cancriniformis* possesses somewhat coarser rugae than the present species and more pronounced ears. Species allied to *C. cancriniformis* from the Early Permian of Siberia (Zavodovsky & Stepanov 1971) are insufficiently known for detailed comparison. The *C. altissima* King of Grunt and Dmitriev (1973) from the Sakmarian of the Pamirs is a small species, with distinct fine rugae, that is close to juvenile specimens of *C. irwinensis*. *C. cancriniformis* from the Late Sakmarian or Early Artinskian of southern Thailand (Waterhouse 1981) is close to *C. irwinensis* in details of costellae and rugae but the overall shell shape of the Thai species is not well known.

Eastern Australian Permian species of *Cancrinella* such as *C. magniplica* Campbell 1953 and *C. gyrandensis* Wass 1966 are large, coarsely rugose species not closely related to West Australian representatives of the genus. *Cancrinella farleyensis* (Etheridge & Dun 1909, pl. 42, figs 9-11; Reid 1929, p. 83, fig. 37.4; McClung 1980, fig. 7) is also large but has weaker rugae and finer costellae than other eastern Australian species. New Zealand Permian species are close to eastern Australian representatives of the genus (Waterhouse, 1964, 1982a).

Age and Stratigraphic Range: Fossil Cliff Member, Perth Basin; Callytharra Formation, Carnarvon Basin; Cuncudgerie Sandstone, Canning Basin; Sterlitamakian (Late Sakmarian).

Cancrinella bella (Etheridge 1918)

Figs 1Q-X, 2A, B

1918 *Productus bellus* Etheridge, p. 254, pl. 39, figs 4, 5; pl. 40, fig. 6.

1926 *Productus bellus* Etheridge; Glauert (*partim.*) *Bull. geol. Surv. W. Aust.*, 88: 46.

1935 *Linoproductus cancriniformis*: Prendergast (*partim.*), p. 14, pl. 2, figs 11-12 (non. cet.).

1943 *Linoproductus cancriniformis*: Prendergast (*partim.*), p. 23.

1957 *Linoproductus cancriniformis*: Coleman (*partim.*), p. 40-69, pl. 8, figs. 2-9 (*non. cet.*).

Lectotype: Ventral valve, AMF16742, figured by Etheridge (1918, pl. 39, fig. 5) herein selected.

Material and Localities: Etheridge's (1918) syntypic series of 4 ventral valves and 1 dorsal valve from Mt. Marmion, Noonkanbah Formation, Canning Basin was reexamined. CPC19919, a ventral valve, from BMR locality KNF76, type section of Noonkanbah Formation, 6.8 km at 298° from Bruten's Old Yard, Cherrabun Station, about 400 m above base of section. MUGDF6028, a ventral valve from a generalised collection labelled "Calceolispongia bed, east limb of syncline at Minilya River", collector C. Teichert, Wandagee Formation, Carnarvon Basin.

Diagnosis: Small to medium sized *Cancrinella*. Moderately convex ventral valve. Rugae strongly developed on ears but weak to absent across venter. Costellae distinct, coarse. Dorsal valve flat on visceral disc, distinctly geniculate.

Description: Species small to medium sized, subquadrate to rounded in outline. Maximum width slightly greater than hinge width. Shell surface marked by distinct, concentric rugae on ears and posterior extremities of the flanks. Rugae absent or very weakly developed across venter. Large gerontic ventral valve (Fig. 1X) has distinct, relatively fine, rugae anteriorly. Costellae well developed, rounded with narrow interspaces, about 1 to 1.5 per mm at 1.5 cm from the umbo, and relatively coarse. Spines arranged in strong tuft of two rows on ears, body spines arise from anterior end of elongate, swollen costellae and extend anteriorly at low angle to shell surface. Body spines relatively dense and arranged in quincunx. Dorsal valve exterior with elongate dimples, costellae and wrinkles, the latter only developed prominently on ears.

Profile of ventral valve convex; no specimen has a marked trail. Ventral umbo small, overhangs dorsal umbo. Ears distinct, usually pointed.

Dorsal valve flat in region of visceral disc, distinctly geniculate on trail. Dorsal interior with normal *Cancrinella* type cardinal process and thick, strong septum approximately two-thirds of valve length. Low, broad marginal ridge extends around posterior of visceral disc.

Ventral interior unknown.

Discussion: *Cancrinella bella* is distinguished from *C. irwinensis* by its less strongly convex ventral valve, coarser costellae, concentric rugae that are absent or only weakly developed on the venter except in old age, distinctly geniculate dorsal valve, and more closely spaced spines. *C. bella* is closer to *C. coolkilyaensis* sp. nov. in details of ornament but has a less strongly convex ventral valve and weaker, finer rugae on the ears and lateral slopes.

The coarser costellae, and lack of well defined rugae on the venter of smaller representatives of *C. bella* recalls the external appearance of species such as *C. singletoni* Gobbett 1964 from the Upper Wordiekammen Limestone, Bunsow Land, Spitzbergen and *C. crassa* Gobbett 1964 from the *Cyathophyllum* Limestone, Spitzbergen. Gobbett's species belong to the group of *C. cancrini* and tend to have even more poorly developed rugae on their ears than those of *C. bella* and also tend to be more strongly convex ventrally. Spine bases on *C. singletoni* are coarser than those of *C. bella.*

C. bella was included, with specimens now attributed to *C. irwinensis*, in *Linoproductus cancriniformis*, (Prendergast 1935, 1943, Coleman 1957). Coleman (1957, pl. 8, figs 2-9) figured several specimens from the Wandagee Formation that can confidently be attributed to *C. bella* on the basis of relatively coarse costellae and ill defined to absent rugae over the venter.

Age and Stratigraphic Range: Noonkanbah Formation, Canning Basin; Wandagee Formation, Carnarvon Basin. Late Baigendzinian (Latest Artinskian).

Cancrinella coolkilyaensis sp. nov.

Fig. 2C-O

1957 *Linoproductus cancriniformis*: Coleman (*partim.*), p. 69, pl. 8, fig. 1 (*non. cet.*).

Etymology: From Coolkilya Paddock on Wandagee Station.

Holotype: CPC19920A, a ventral valve internal mould from the Coolkilya Greywacke, Carnarvon Basin.

Material and Localities: CPC19920A-19920G, 4 internal moulds of ventral valves, 1 external mould of a ventral valve, 1 incomplete internal mould of a conjoined shell and 1 external mould of a dorsal valve all from BMR locality ML79, 2.4 km south east of Trig. Point on Wandagee Hill, Coolkilya Greywacke, Carnarvon Basin. UWA88109-88111, 3 internal moulds of ventral valves from UWA L12, *Linoproductus* section east of Wandagee Hill, Nalbia Paddock, horizon 1, collector C. Teichert, now in Coolkilya Greywacke.

Diagnosis: Medium sized *Cancrinella*. Strongly convex ventral valve. Weakly rugose shell with low rugae extending across venter. Spines relatively fine and costellae relatively coarse. Ears and lateral slope extremities coarsely rugose. Dorsal valve strongly geniculate.

Description: Species medium-sized for genus, elongate in maturity with straight sides. Maximum width greater than hinge width. Shell surface marked by concentric rugae, coarse and distinct on ears and extremities of lateral flanks and weakly present across venter of shell. Rugae stronger on trail of ventral valve. Costellae rounded with narrow interspaces, about 1 to 1.5 per mm at 1.5 cm from ventral umbo. About 5 rugae per cm in

TABLE 2
MEASUREMENTS OF *Cancrinella coolkilyaensis* sp. nov. (in mm)
* = holotype; e = estimate; † = incomplete specimen

Specimen number	Maximum width	Hinge width	Ventral length	Dorsal length	Thickness
UWA88109	23.6	19.0e	28.2	–	18.6
UWA88110	23.0†	–	–	–	–
UWA88111	19.4†	–	–	–	–
CPC19920A*	25.0	–	23.2	–	14.1
CPC19920B	22.2	25.0e	21.0e	–	11.2
CPC19920C	20.2	19.0	–	–	–
CPC19920D	–	–	13.0e	–	–
CPC19920E	–	–	16.5†	13-5e	–
CPC19920F	26.0	–	–	15.3	–

the second cm of growth. Spines arranged in tuft of two rows on ears; body spines, only slightly wider than costellae, arise from anterior extremities of elongate, somewhat swollen costellae, extend anteriorly at low angle to shell surface. Dorsal valve distinctly rugose over visceral disc, strongly rugose on trail with strong costellae and elongate dimples.

Profile of ventral valve strongly convex, with convexity of trail being less than that of posterior of valve. Ventral umbo small, overhangs dorsal umbo. Ears distinct, pointed in outline.

Dorsal valve flat on visceral disc, strongly geniculate anteriorly, initially at 70°-80° and anteriorly up to 120° from plane of visceral disc.

Ventral interior may carry numerous elongate narrow ridges over visceral disc of valve (specimen CPC19920A). Dorsal interior poorly known, traces of delicate median septum occur on specimen CPC19920E.

DISCUSSION: *Cancrinella coolkilyaensis* is distinguished from *C. irwinensis* by its coarser costellae, weaker rugae and strongly geniculate dorsal valve. *C. bella* is closer to *C. coolkilyaensis* but possesses a less convex ventral valve, and possibly a less geniculate dorsal valve in addition to a lacking or having weak rugae over the venter of specimens of comparable size; its dorsal valve has weaker rugae. The new species is close to *Cancrinella* sp. (Archbold 1982b) from Late Baigendzinian/Early Kungurian black shales of Irian Jaya in terms of ventral convexity and development of rugae. The Irian Jaya species, however, possesses finer costellae than *C. coolkilyaensis*.

AGE AND STRATIGRAPHIC RANGE: Coolkilya Greywacke, Carnarvon Basin. Middle Kungurian.

Cancrinella sp. A
Fig. 2P-R

MATERIAL AND LOCALITIES: CPC19921A-C, 1 internal mould of a dorsal valve, 1 external mould of a dorsal valve and 1 internal mould of a ventral valve all from BMR locality GW54, 7.6 km from Dairy Creek Homestead on bearing of 115°, on south bank of Bush Creek, Coyrie Formation, Carnarvon Basin, GSWA11193A, B, 1 internal mould of a dorsal valve and 1 internal mould of a ventral valve from GSWA locality 44563, Glenburgh (1970) Run 9/047, pt. 322, EVG, BK8, Madeline Formation, Yard Grid 350-776, Carnarvon Basin.

DESCRIPTION: Specimens small and incomplete. Ventral valve internal moulds poorly preserved but indicate strong convexity and characteristic long, thin internal ridges. Rugae irregularly developed on ventral valves, not strongly raised. Dorsal valves possess pronounced, fine rugae, distinct, fine costellae and shallow, elongate dimples. Cardinal process minute and bilobed, median septum ill defined and short.

DISCUSSION: Although inadequate for detailed comparison this species is closest to *C. irwinensis* which species is distinguished by its distinct, fine rugae, regularly spaced, on the ventral valve.

AGE AND STRATIGRAPHIC RANGE: Coyrie and Madeline Formations, Carnarvon Basin. Early Baigendzinian (Middle Artinskian).

Cancrinella sp. B
Fig. 2S-V

MATERIAL AND LOCALITY: CPC19922A, B, 2 ventral valves from BMR locality ML51, Minilya River, north side, Minilya Syncline, 5 km west of Cundlego Well, *Cleiothyridina Strophalosia* horizon, early Kungurian, Norton (now Nalbia) Sandstone.

DESCRIPTION: Ventral valves strongly convex. Ears small and subquadrate. Rugae fine and low over visceral disc but coarse and prominent over pronounced trail. Ventral valve distinctly geniculated. Costellae relatively fine (2 per cm at 1 cm from the umbo), rounded and separated by narrow interspaces. Spine bases coarse (about the width of three costellae) and arise from swollen costellae. Body spines project at a low angle. Ear spines arranged in tuft formed by 2 rows of spines. Ventral umbo small pointed. Mature valve elongate with maximum width about mid length of valve.

Fig. 2—A-B, *Cancrinella bella* (Etheridge); from Noonkanbah Formation, Canning Basin. A-B, AMF16735, dorsal valve in ventral view, ×1.2 and ×4.5. C-O, *Cancrinella coolkilyaensis* sp. nov.; all from Coolkilya Greywacke, Carnarvon Basin. C-F, Holotype, CPC19920A, ventral valve internal mould in ventral, posterior and two lateral views, ×1.4. G, CPC19920G, ventral valve external mould, ×1.2. H-I, CPC19920B, ventral valve internal mould in postero-ventral and ventral views, ×1.5. J, UWA88111, ventral valve internal mould in ventral view, ×1.2. K, CPC19920E, incomplete internal mould of conjoined shell in dorsal view, ×1.5. L, UWA88110, ventral valve internal mould in ventral view, ×1.5. M-O, CPC19920F, external mould of dorsal valve in dorsal, interior and lateral views, ×1.4, P-R, *Cancrinella* sp. A, P-Q, from Coyrie Formation, Carnarvon Basin; R, from Madeline Formation, Carnarvon Basin. P, CPC19921A, dorsal valve internal mould, ×1.6. Q, CPC19921B, dorsal valve external mould, ×1.8. R, GSWAF11093A, ventral valve internal mould, ×1.8. S-V, *Cancrinella* sp. B; from Nalbia Sandstone, Carnarvon Basin. S-U, CPC19922A, ventral valve in posterior, ventral and lateral views, ×1.8. V, CPC19922B, ventral valve in ventral view, ×1.8.

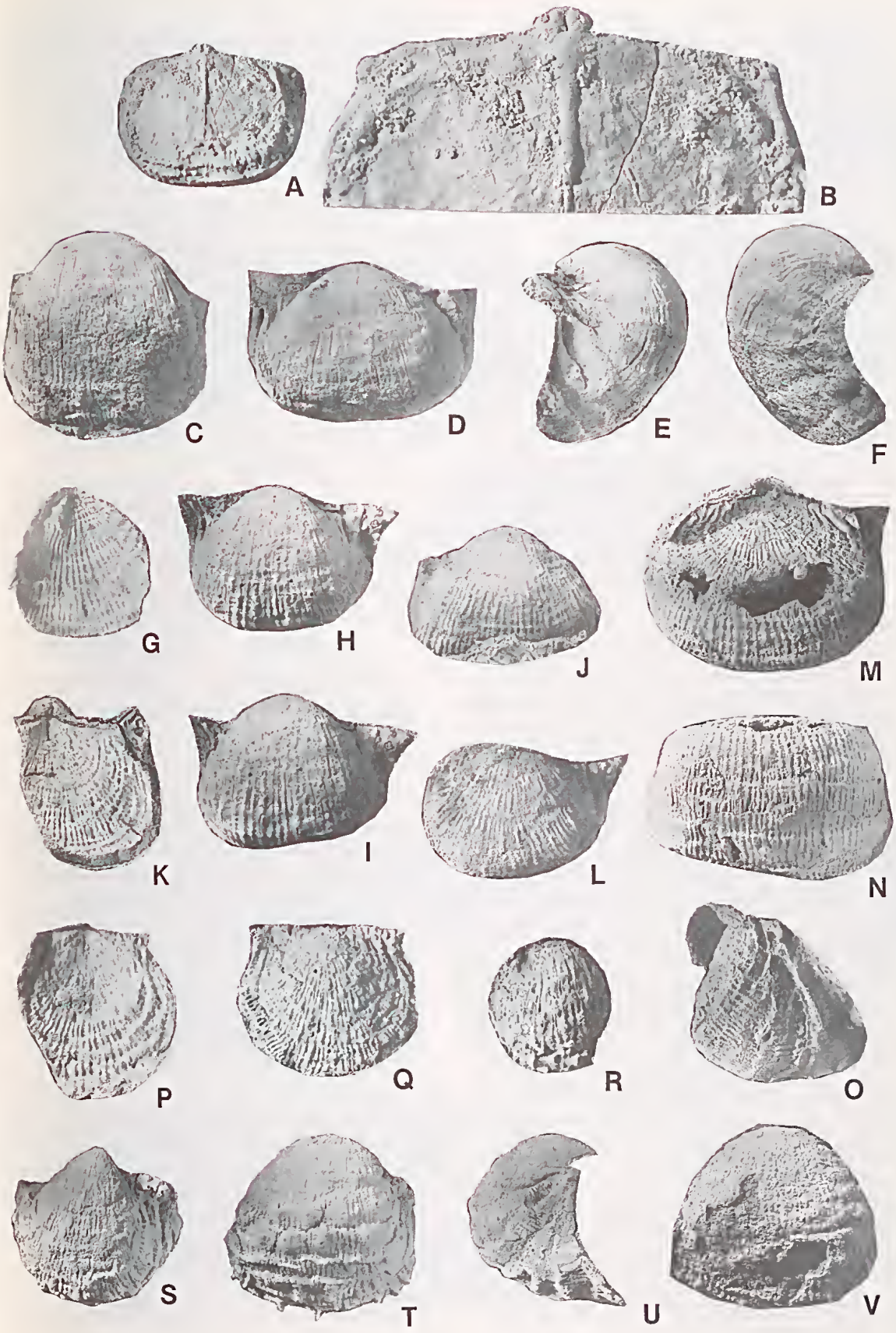
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TABLE 3
MEASUREMENTS OF *Cancrinella* sp. B
e = estimate

Specimen number	Hinge width	Maximum width	Ventral length	Thickness
CPC19922A	14.0	17.0	18.2	12.5
CPC19922B	—	18.0	16.5	—

DISCUSSION: The highly convex ventral valve, coarse rugae on the trail and coarse spine bases indicate a distinct species. Spine bases and rugae are much coarser than those of *C. coolkilyaensis*. *C. bella* possesses relatively coarse spine bases but much more weakly developed rugae. The strongly developed rugae recall those of *C. magniplica* Campbell 1953 from the Kungurian of Queensland, but the east Australian species is much larger and somewhat less convex.

Genus **Lyonia** nov.

TYPE SPECIES: *Linoproductus cancriniformis* var. *lyoni* Prendergast 1943.

DIAGNOSIS: Moderately large, relatively gently concavo-convex linoproductinids, wider than long, maximum width at or close to hinge line. Hinge extremities flattened into large ears but not clearly demarcated from rest of valve. Ventral valve evenly convex—no flattening or sulcus, no distinct trail. Ventral ornament of fine rugae over entire valve, slightly stronger over ears and lateral flanks, distinct costellae, increasing in number normally by bifurcation, and spines. Spines as single row of curved hinge spines, smaller towards umbo and scattered body spines, in a generalised quincunx, arising from slightly swollen costellae. Ventral valve thin, internal ornament reflects external ornament, muscle scars vague even in largest specimens.

Dorsal valve thin, gently concave, weakly geniculate anteriorly; exterior ornament of fine rugae, distinct costellae, swollen elongate dimples and fine irregularly developed spines which are only developed after the initial 1.5 cm of growth of shell. Dorsal interior with fine median septum arising anteriorly of low, thickened pad which in turn is anterior of cardinal process. Cardinal process low and squat, not supported by septum, barely projects beyond hinge, weakly quadrilobed interiorly, narrow and weakly bilobed exteriorly. Pair of low, broad ridges diverge from base of process; low marginal hinge ridges carry row of raised pustules (correspond to ventral hinge spines ?). No brachial ridges; interior ornament reflects exterior ornament.

DISCUSSION: *Lyonia* is a distinctive monotypic genus. *Lyonia lyoni* is readily distinguished from *Linoproductus* by its external ornament, and from *Cancrinella* especially west Australian species, by its much larger size and more gentle ventral convexity (the latter is not an artefact of flattening or crushing). The presence of dorsal spines appears to be atypical of *Cancrinella* (see Waterhouse & Gupta 1978). Nevertheless the dorsal interior of *L. lyoni* is quite distinct from that of *Cancrinella* where the cardinal process projects distinctly beyond the hinge line and is strongly supported by the median septum. The marginal hinge ridges of *Cancrinella* appear to lack the row of pustules that are present in *L. lyoni* (see Grigor'eva *et al.* 1977). The cardinal process of *Lyonia* recalls that of *Spitzbergenia* Kotlyar (in Grigor'eva *et al.* 1977), as shown in *S. gracilis* Kotlyar from the Late Permian Selandersk Suite of Spitzbergen, but Kotlyar's genus possesses stronger marginal ridges, a different median septum arrangement, weaker rugae over the shell and appears to lack dorsal spines. *Lyonia* may be ancestral to *Spitzbergenia*. *Auriculispina* Waterhouse 1975 from the early Permian of Queensland can be distinguished from *Lyonia* by its numerous ear spines, lack of dorsal spines and different dorsal median septum. *Bandoproductus* Jing & Sun (1981) is also close to *Lyonia* but lacks dorsal spines and has a higher cardinal process. The dorsal median septum of *Bandoproductus* is short and low when compared with that of *Lyonia*.

Lyonia lyoni (Prendergast 1943)
Fig. 3

1943 *Linoproductus cancriniformis* var. *lyoni*. Prendergast, p. 24, pl. 3, figs 1-2.
1957 *Linoproductus lyoni* Prendergast; Coleman (*part-tim.*), p. 76, pl. 8, figs 16-22.

HOLOTYPE: AMF36530, ventral valve, from 10 chains north west of Gnarrea Pool near Winning Station, Lyons Group, Carnarvon Basin.

MATERIAL AND LOCALITY: CPC19923A-F, 1 ventral valve, 1 ventral valve internal mould, 1 ventral valve external mould, 1 dorsal valve external mould and 2 dorsal valve internal moulds were measured. These and some 15 additional specimens of variable preservation are from BMR locality T23 (F17690 and F17692) approximately 4.8 km northeast of Round Hill Well, 210 m west of Kialawibri Creek road crossing, Winning Station, Carnarvon Basin, Lyons Group. Prendergast's (1943) syntypic series was re-examined.

Fig. 3—A-P, *Lyonia lyoni* (Prendergast); all from Lyons Group, Carnarvon Basin. A-B, CPC19923A, ventral valve in posterior and ventral views, ×1. C, CPC19923F, internal mould of dorsal valve, ×1. D, F-G, I-K, CPC19923D, internal mould of dorsal valve, ×1, latex replica of dorsal valve internal mould in ventral view, ×1.2, enlargements of mould of cardinal area, ×6, and ×3.5 respectively, enlargement of latex replica of cardinal region, ×4.5. E, CPC19923C, incomplete external mould of ventral valve, ×1.H, CPC19923B, ventral valve internal mould in ventral view, ×1. J, L, CPC19923E, dorsal valve external mould, ×1, enlargement of anterior of dorsal valve external mould, ×10. M, AMF36530, rock slab with holotype (ventral valve in upper right) and dorsal valve internal mould, ×0.6. N-O, AMF36530, holotype, ventral valve in ventral view, ×1, enlargement of hinge spines, ×2. P, AMF36530A, dorsal valve internal mould on slab of rock with holotype, ×1.

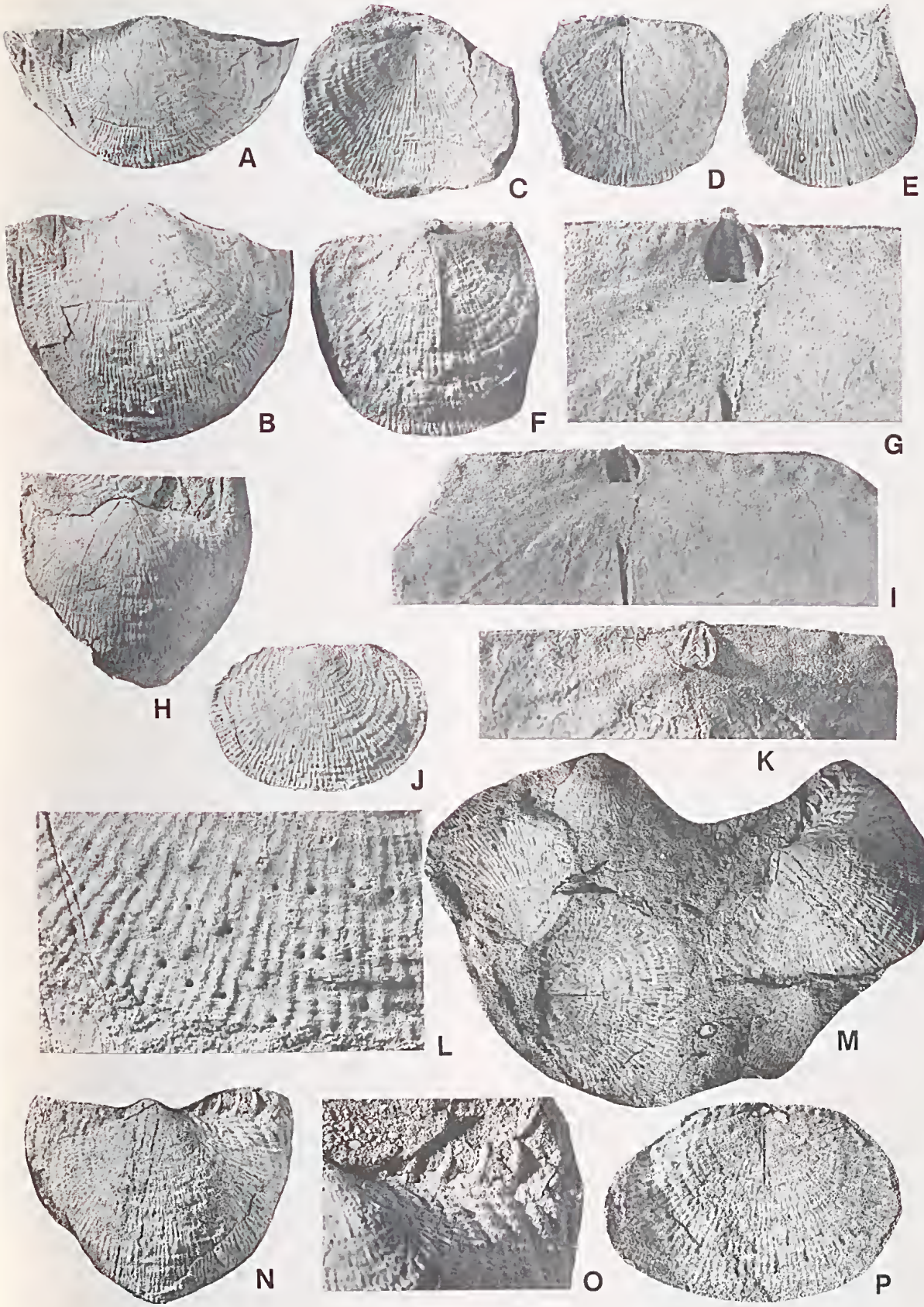
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TABLE 4
MEASUREMENTS OF *Lyonia lyoni* (Prendergast 1943)
e = estimate; † = incomplete specimen

Specimen number	Maximum width	Hinge width	Ventral length	Dorsal length	Thickness	Dorsal septum length
CPC19923A	49.0e	49.0e	41.4	–	16.0e	–
CPC19923B	37.2e	36.5	27.5	–	12.5e	–
CPC19923C	–	–	26.0	–	–	–
CPC19923D	30.0e†	28.0e†	–	25.3	–	12.0
CPC19923E	29.8	–	–	22.0	–	–
CPC19923F	29.0	–	–	25.0	–	9.0

DIAGNOSIS: As for genus.

DESCRIPTION: Shell medium to large sized and transverse. Ventral valve evenly and moderately convex both transversely and in longitudinal profile; dorsal valve gently concave and weakly geniculated anteriorly (only by an increase of about 10° in concavity). Maximum shell width at or close to the hinge line. Ears large and flattened but not clearly demarcated from the rest of valves. No flattening or sulcus in ventral valve and no distinct ventral trail. Ventral valve with distinct ornament of relatively fine rugae over entire valve (about 10 per cm at 2 cm from umbo and about 6 per cm at 3.5 cm from umbo); rugae slightly stronger on ears and lateral flanks of valve. Costellae distinct (15 per cm at 2 cm from umbo and 10 per cm at 4 cm from umbo), rounded with narrow interspaces; cover entire ventral valve. Ventral spines of two types: a single row of curved hinge spines, smaller towards the umbo, and scattered, quincunxially arranged body spines over the remainder of the valve, growing from slightly swollen bases and arising from a single costella. Costellae invariably bifurcate anteriorly of spine bases and increase in number elsewhere on shell by bifurcation. Spines project forward at low angle to ventral valve. Ventral valve thin, internal ornament reflects the external ornament; muscle marks vague and ill defined even in largest specimens.

Dorsal valve thin, with external ornament of fine rugae, distinct costellae, swollen elongate dimples and fine, irregularly developed, erect spines, the latter only developed after initial 1.5 cm of growth. Dimensions of rugae and costellae similar to those for ventral valve. Body spines of ventral valve about 0.8 mm thick those of dorsal valve 0.3 mm thick. Dorsal interior with fine median septum arising anteriorly of low, thickened pad which, in turn, is anterior of low, squat cardinal process. Cardinal process not supported by septum, barely projects beyond hinge line; interior face of process with weakly divided, large median lobe and smaller lateral lobes giving a weakly quadrilobate appearance. Pair of low, broad ridges diverge from base of process and low, marginal hinge ridges carry row of raised pustules. No brachial ridges and interior ornament of valve reflects that of exterior.

DISCUSSION: Well-preserved dorsal valves are not known for species from New South Wales and Queensland that have been compared with *Lyonia lyoni* (Maxwell 1964, Runnegar 1969, Degeling, & Runnegar 1979), but detailed comparison with true *Lyonia lyoni* is not possible until well preserved dorsal valves of the eastern Australian species are described and figured. The same is true for *L. lyoni* from the Tastubian of Afghanistan (Lapparent *et al.* 1971). *Cancrinelloides monticulus* Waterhouse (1982b) from the Asselian of southern Thailand, lacks dorsal spines and is distinct from *L. lyoni* in other ornamental details, such as density of ventral spine bases, as well as dorsal internal structures. It may be better assigned to *Bandoproductus*.

Coleman (1957) specimens (UWA32036, 32037a, 32037b) from the Callytharra Formation are re-assigned to *Cancrinella irwinensis*, a variable species, at times of large size.

AGE AND STRATIGRAPHIC RANGE: Lyons Group, Carnarvon Basin and Fossil Cliff Member, Perth Basin. Tastubian—possibly ranging to early Sterlitamakian.

Subfamily STEPANOVIELLINAE Waterhouse 1975

DIAGNOSIS: Linoproductinid shells with dominant costellate/capillate ornament and smooth, lobate ventral adductor scars at times dendritic anteriorly; small to medium-sized for family. Shell with subquadrate outline, ventral valve thickened.

GENERA INCLUDED AND DISCUSSION: The Stepanoviellinae, revised herein to include *Stepanoviella* Zavadovsky 1960, *Globiella* Muir-Wood & Cooper 1960 and *Liraria* Cooper & Grant 1975, is a distinctive group of linoproductids characterised by prominent fine radial ornament and by the possession of smooth, lobate, at times dendritic anteriorly, ventral adductor scars.

Waterhouse (1975) placed the Stepanoviellinae in the Anidanthidae. Recognition of the Anidanthidae has merit (Grigor'eva & Kotlyar 1977), but in view of the distinctive shape and ornament of the Stepanoviellinae, that subfamily is referred to the Linoproductidae. Waterhouse (1975, 1978a) stressed the nondendritic nature of the ventral adductors in his concept of the Stepanoviellinae. However, the nature of the ventral adductor scars should be used with caution in the classification of these productids. Waterhouse (1978a), while disputing the value of the genus *Pseudostrophalosia* Clarke (1970), stressed that dendritic ventral adductor scars develop late in ontogeny in the Strophalosiidae as in the Anidanthidae. *Yakovlevia* Fredericks (1925) possesses dendritic posterior adductor scars and lobate anterior adductor scars in the ventral valve. Grigor'eva *et al.* (1977) contrary to Muir-Wood and Cooper (1960) and Waterhouse (1970) have indicated that both *Stepanoviella* and *Globiella* possess elongate, dendritic adductor scars. Examination of specimens referred to *Globiella* from western Australia and India indicates that in old age the ventral anterior adductor scars of both species become weakly dendritic while the posterior adductor scars remain smooth.

Genus **Globiella** Muir-Wood & Cooper 1960

TYPE SPECIES: *Productus hemisphaerium* Kutorga 1844.

Diagnosis: Medium sized shell, hemispherical, narrowing anteriorly producing elongate-oval outline in maturity; non-geniculate valves; ears small; umbo tiny; hinge width close to maximum width; both valves covered with fine radial costellae, at times flexuous anteriorly, bifurcating; dorsal valve with variably defined rugae; spines restricted to ventral valve, in row along hinge, increasing in size, rare or absent elsewhere on valve. Interior of ventral valve with weak ridges delimiting ears, smooth lobate to dendritic adductor scars and longitudinally striate diductor scars; dorsal interior with small, trilobate cardinal process; median septum on adult examples merged posteriorly into two fused ridges.

Discussion: The above diagnosis is modified from those given by Muir-Wood and Cooper (1960) and Grigor'eva *et al.* (1977). Mature specimens of *Globiella foordi* possess poorly defined dendritic adductor scars and hence it is probably a feature that develops late in ontogeny. Grigor'eva *et al.* (1977) adopted a narrow diagnosis and range for the genus, but by enlarging the diagnosis, a large, widely distributed group of Gondwanan species can be included within *Globiella*. As noted by Fantini Sestini (1966) and Waterhouse (1970) the dorsal valve of many of these species is poorly known and hence assignment of various species to *Globiella* can only be provisional. Nevertheless, sufficient details of many of the species are known, to indicate that if they do not belong to *Globiella* they belong to a closely related (new) genus.

Grigor'eva *et al.* (1977) distinguished *Globiella* from *Stepanoviella*, the latter usually being treated as a senior synonym of *Globiella* (Grigor'eva 1962, Muir-Wood 1965, Waterhouse 1970). *Stepanoviella* Zavadovsky (1960), as restricted by Grigor'eva *et al.* (1977) carries two types of ventral spines—"inclined" and "straight"—as well as fine spines on the dorsal valve. *Stepanoviella* is characterised by extremely fine costellae and is reliably known only from the Late Permian of north-east Siberia.

Liraria Cooper & Grant (1975) is provisionally referred to the Stepanoviellinae. It is readily distinguished from *Globiella* by its transverse outline and poorly developed dorsal median septum, although otherwise the interior of the dorsal valves of both genera are somewhat similar (Cooper & Grant 1975).

Globiella umariensis (Reed 1928)

Fig. 4A-L

1928 *Productus umariensis* Reed. 371, pl. 31, figs 1-6; pl. 32, figs 4-8.

1928 *Productus umariensis* var *spinifera* Reed. 375, pl. 33, figs 1-6; pl. 35, fig. 9.

1928 *Productus rewahensis* Reed. 376, pl. 32, figs 1, 1a; pl. 35, figs 1-7.

1928 *Productus rewahensis* var *coroides* Reed. 378, pl. 32, figs 2-3a; pl. 35, figs 8-8a.

1965 *Globiella umariensis* (Reed), Mitra and Chakraborty. 91.

1977 *Stepanoviella umariensis* Sastry *et al.*, *Misc. Publ. Geol. Surv. India* 36: 94, pl. 1, fig. 5.

Syntypes: Series figured by Reed (1928, pl. 31, figs 1-6; pl. 32, figs 4-8).

Material and Locality: CPC19924A-M, 9 ventral valves, 3 ventral valve internal moulds (2 measured) and 1 incomplete dorsal valve all from Marine Bed (latest Tastubian), Narsarha railway cutting, Umaria, Madhya Pradesh, India; topotypes.

Table 5
Measurements of *Globiella umariensis* (Reed, 1928) in mm.
e = estimate; † = incomplete specimen

Specimen Number (alt CPC)	Hinge width	Maximum width	Ventral length	Thickness	Length dorsal septum
19924A	32.0e	38.9	31.8	14.3e	–
19924B	29.2†	33.0†	26.8	12.8e	–
19924C	32.0e	34.0e	28.8	9.5e	–
19924D	29.5†	32.6	30.6	14.0e	–
19924E	28.0	28.0	23.0†	–	–
19924F	28.0†	33.0†	25.0†	–	–
19924G	27.0†	32.0†	–	–	–
19924H	–	–	28.5	–	–
199241	26.4	37.0	–	–	–
19924J	16.5	21.4	16.5	–	–
19924K	–	36.0e	25.0†	–	–
19924L	–	16.0e	–	–	7.2

Diagnosis: Large *Globiella*, transverse to elongate. Ventral valve with rugae on ears, at times on lateral flanks. Ventral spines, in row along hinge, variably developed over valve. Ventral valve convexity moderate for genus.

Description: Shell outline transverse from youth into maturity, becoming elongate in old age. Ventral valve with convexity increasing with old age; dorsal valve gently concave, not geniculated. Maximum shell width at hinge line from youth into maturity but moves to midlength of shell in old age. Ears small but distinct, clearly demarcated from rest of ventral valve by pronounced flattening. No flattening or sulcus in ventral valve and no demarcated ventral trail. Hinge line straight, carries row of ventral hinge spines, increasing in size away from small, pointed umbo. Spines variably developed over body of ventral valve, on some specimens extremely rare, other specimens carry spines at 5 mm intervals or closer. Body spines fine, arise from single costella, and project anteriorly at low angle to valve. Spine bases not swollen. Fine rugae developed on ears of ventral valve, variably developed on lateral flanks; they do not cross venter as distinct rugae but several specimens show 2-3 low wrinkles (best seen in oblique light) on anterior of venter. Costellae distinct, increase in number by intercalation and bifurcation, fine (10-11 per 5 m at 1 cm from umbo and 8-9 per 5 mm at 2 cm from umbo), rounded and interspaces narrow. Ventral valve thin but external ornament not shown on

interior of valve. Muscle marks moderately clear; adductor scars posteriorly located and smooth in most specimens; specimen CPC19924M, an incomplete ventral valve internal mould, appears to possess striate or vaguely dendritic anterior adductor scars. Diductor scars large, broad and ridged with low branching ridges.

Dorsal valve thin, concave, with an external ornament of poorly developed, fine concentric wrinkles and distinct costellae, the latter being similar to those of ventral valve. Dorsal valve exterior appears to lack spines. Exterior ornament not reflected on interior of visceral disc despite shell being thin. Thin median septum extends from the base of cardinal process. Brachial ridges and cardinal process unknown but former not developed in one dorsal interior available to me.

Discussion: Although originally described (Reed 1928) as two species and two varieties, this species was revised (Mitra & Chakraborty 1965) as one. I have examined two blocks from the type locality and concur with Mitra and Chakraborty (1965) on the variability of the species.

Details of the dorsal valve remain to be clarified—particularly the cardinal process and brachial ridges. Mitra and Chakraborty (1965, p. 92) indicated dorsal spines but Reed (1928) did not describe them and the fragmentary material available to me does not carry spines. I regard the species as lacking dorsal spines. Detached ventral spines of *G. umariensis* from the Umaria marine bed have been described and figured by Bhatia (1959) and Gupta (1971).

Many specimens of *G. umariensis* are of similar general outline to *L. lyoni* but the difference in internal ornament, spinosity (when it occurs in *G. umariensis*) and the dorsal septum indicate that the two species are not closely related. *G. umariensis* is assigned to *Globiella*, following Muir-Wood and Cooper (1960), rather than to *Stepanoviella* in the restricted sense (Grigor'eva *et al.* 1977). Nevertheless *G. umariensis* is an atypical species of the genus, frequently displaying a less globular and less convex appearance than typical *Globiella*.

The poorly known *G. gracilis* (Ching *et al.* 1977) is probably the closest species to *G. umariensis* as the Tibetan species also is only moderately convex ventrally and possesses similar constellae.

G. rossiae Fantini Sestini (1966) from the Early Permian (Aktastinian) of northern Iran is more subquadrate in outline and has finer costellae while the Aktastinian specimens and of the Pamirs (Grunt & Dmitriev 1973) is more strongly rugose than *G. umariensis*. The Pamir species is specifically distinct from *G. rossiae*. Other Early Permian species are discussed under *G. foordi* below.

G. umariensis has been recorded from the Early Permian of Afghanistan (Lapparent *et al.* 1971) but has not been fully described or figured. Specimens from the Early Permian of Afghanistan were compared by Termier and Termier (1971) with *Globiella flexuosa* (Waterhouse 1970b) by Termier and Termier (1971) who also provided a sketch of the dorsal interior with a long, thin median septum similar to that of *G. umariensis*.

Globiella foordi (Etheridge 1903)
Fig. 5

1890 *Productus tenuistriatus*: Foord (*non* de Verneuil). *Geol. Mag., Dec.* III, 7: 151, pl. 7, figs 4, 4a.
1903 *Productus tenuistriatus* de Verneuil (?) var. *foordi* Etheridge, p. 19, pl. 1, figs 3, 4; pl. 5, fig. 22.
1907 *Productus tenuistriatus* var. *foordi* Etheridge fil. *Bull. geol. Surv. W. Aust.*, 27-30, pl. 9, figs 4-6.
1910 *Productus tenuistriatus* var. *foordi* Etheridge fil., Glauert. *Bull. geol. Surv. W. Aust.*, 36: 37.
1931 *Productus tenuistriatus* var. *foordi* Etheridge fil., Hosking. *J. Roy. Soc. W. Aust.* 17: 8, 22.
1933 *Linoproductus* cf. *Linoproductus tenuistriatus* var. *foordi* (Etheridge, fil.), Hosking. *J. Roy. Soc. W. Aust.* 19: 47, pl. 4, fig. 3.
1937 *Linoproductus tenuistriatus* var. *foordi* (Etheridge fil.), Raggatt Fletcher. *Rec. Aust. Mus.* 20: 175.
1943 *Linoproductus cora* var. *foordi* (Etheridge), Prendergast, p. 22, pl. 3, figs 3-5.
1957 *Linoproductus cora. foordi* (Etheridge), Coleman, p. 74, pl. 8, figs 10-15.
1971 *Stepanoviella foordi* (Etheridge), Waterhouse. *Proc. Pap. 2nd Gondwana Symp.*, p. 391.

Lectotype: GSWAF156B selected by Crespin (1964, p. 68). Although stated to be the holotype by Crespin (1964), Etheridge (1903) did not select a type specimen. The specimen is from the Callytharra Formation at Fossil Hill. Wyndham River, Carnarvon Basin.

Material and Localities: GSWA11193A-F, 6 ventral valves from Fossil Cliff, Irwin River, Fossil Cliff Member, Perth Basin; CPC19925, ventral valve internal mould from BMR locality 1R20, Carynginia Gully, 2.8 km on a bearing of 297° from Carynginia Well, Fossil Cliff Member; CPC19926A-C, 3 ventral valves from BMR locality GW87, Lat. 25°52′, Long. 115°30′, 10 to 17 m above base of Callytharra Formation, Carnarvon Basin; CPC19927A B, 2 ventral valves from BMR locality GW89, as for GW87, 17 to 21 m above

Fig. 4—A-N, *Globiella umariensis* (Reed), all from Umaria Marine Bed, India. A-B, CPC19924K, ventral valve in ventral and posterior views, ×1. C, CPC19924D, ventral valve in ventral view, ×1. D-E, CPC19924B, ventral valve internal mould in ventral and posterior views, ×1. F, CPC19924J, ventral valve in ventral view, ×1. G, CPC19924G, ventral valve in ventral view, ×1. H, CPC19924L, dorsal valve interior, ×1. I, CPC19924F, ventral valve in ventral view, ×1. J-L, CPC19924E, ventral valve in anterior, ventral and lateral views, ×1. M-N, CPC19924A, ventral valve in posterior and ventral views, ×1. O-Z, AA-BB, *Globiella flexuosa* (Waterhouse), all from Jimba Jimba Calcarenite, Carnarvon Basin. O, MUGDF6030B, ventral valve in ventral view, ×1. P-Q, MUGDF6030D, ventral valve in ventral and posterior views, ×1. R-S, MUGDF60301, ventral valve in ventral and posterior views, ×1. T-U, MUGDF6030A, ventral valve in ventral and posterior views, ×1. V-X. MUGDF6030C, ventral valve in ventral, postero-ventral and posterior views, ×1. Y, MUGDF6030B, ventral valve in posterior view, ×1. Z, AA, MUGDF6030F, ventral valve in ventral and posterior views. BB, MUGDF6030G, ventral valve in dorsal view, ×1.


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base of Callytharra Formation; CPC19928A, B, 2 natural casts of ventral valves from BMR locality G202, 9.2 km, bearing 335° from Lyons River Homestead, Callytharra formation; GSWA11194, a ventral valve from GSWA locality 44594, Yaringa (1968) Run 4/138, pt. 505 EVG BK9, Callytharra Formation, yard grid 343-726; GSWA11195, a ventral valve from GSWA locality 44559, Glenburgh (1970), yard grid 356,793, Photo Run 8/062, EVG BK8, pt. 277, Callytharra Formation: GSWA11196A-E, 4 ventral valves and 1 dorsal valve from GSWA locality 44573, Glenburgh (1970) Run 8/060, pt. 368, Callytharra Formation, type section, Callytharra Springs; MUGDF6029A-F, 6 ventral valves, from G. A. Thomas locality P498, type section, Callytharra Formation, Callytharra Springs, 34-38 m above base of formation. Sterlitamakian (Late Sakmarian).

TABLE 6
SIZE RANGES OF POPULATIONS OF *Globiella foordi* (Etheridge, 1903) in mm (including 2 gerontic Callytharra specimens).

Stratigraphic horizon	Hinge width	Maximum width	Ventral length	Thickness
Fossil Cliff	19.2-24.1	20.2-27.4	17.5-25.5	8.0-15.3
Callytharra	14.7-25.4	22.0-35.4	19.7-33.5	10.8-17.5
CPC19928A	–	40.0	45.0	26.0
CPC19928B	–	40.0	48.0†	30.0

DIAGNOSIS: Small to very large *Globiella*, transverse to elongate. Ventral valve normally without rugae, occasionally with several low rugae on ears and across venter. Vertral valve with row of hinge spines—no spines on remainder of valve. Ornament of distinct radial costellae, moderately coarse for genus. Dorsal valve with low rugae anteriorly.

DESCRIPTION: Shell outline transverse in youth and subquadrate to circular in maturity; gerontic shells elongate with distinct trail. Ventral valve strongly convex, globular in appearance, dorsal valve distinctly concave. Maximum shell width at hinge line from youth into maturity but moves to anterior of midlength of shell in old age. Ears small, pointed, normally poorly demarcated from body of ventral valve, at times twisted ventrally and hence prominent. No flattening of sulcus in ventral valve, the valve being evenly convex, except in gerontic specimens where convexity flattens out into pronounced trail. Trail in gerontic specimens medianly flat, strongly convex in transverse profile. Hinge line straight with row of ventral hinge spines, larger towards the ears and at low angle to hinge, point away from umbo. Ventral umbo small, pointed, overhangs hinge line. Spines absent over body of ventral valve. Rugae, developed weakly over small ears and posterior lateral flanks, low relatively fine and usually inconspicuous. Rarely, low undulations (or very weak rugae) cross venter of shell. Costellae distinct, increase in number by intercalation; normally straight but may curve and twist; secondary costellae may join primary costellae anteriorly and fuse into single costellae. Costellae normally curve and change orientation at sites of breakage during growth. Costellae sharply rounded and separated by distinct interspaces of about same width as costellae; size of costellae relatively constant (normally 16-18 per cm at 1 cm from umbo and 14-17 per cm at 2 cm from umbo) although a few specimens have finer costellae (e.g. MUGDF6029E, 22 per cm at 1 cm from umbo and 19 per cm at 2 cm from umbo). Ventral valve thin anteriorly, and appears to have been frequently broken during life, but thickened posteriorly along hinge and adjacent to muscle scars; trail particularly thin and normally missing. Muscle marks deep; adductor scars posteriorly located, elongate, lobate and smooth in juvenile specimens, in mature specimens they may be anteriorly ridged in feeble dendritic pattern. Diductor scars large, broad and feebly to strongly ridged and grooved with branching ridges.

Dorsal valve thin, delicate, moderately concave and has external ornament of poorly developed, fine, concentric wrinkles or rugae crossing visceral disc. Costellae distinct and increase by bifurcation; lower and, on available specimens, finer than those of typical ventral valve (19-20 per cm at 1 cm from the umbo). No dorsal spines. Ears distinct and twisted slightly ventrally. Exterior ornament reflected internally on anterior of visceral disc. Smooth adductor scars divided by sharp median septum and again bisected laterally by low ridges. Brachial ridges not developed on one available dorsal interior; cardinal process unknown.

DISCUSSION: The dorsal interior of *G. foordi* appears comparable with that of Sakmarian Afghan specimens compared with *G. flexuosa* by Termier and Termier (1971, fig. 9) although *G. foordi* appears to have a stronger median septum and wider adductor scars.

The remarkable feature of *G. foordi* is the distinctive trail in old age; the same type of trail is known in a gerontic specimen of *Globiella* (*Productus cora* Broili 1915, pl. 21, figs 4a-b) from Bitauni type faunas of Letti.

Fig. 5—A-Z, AA-GG, *Globiella foordi* (Etheridge); A-H, from Fossil Cliff Member, Perth Basin; 1-Z, AA-GG, from Callytharra Formation, Carnarvon Basin. A-B, GSWAF11193B, ventral valve in ventral and posterior views, ×1. C-E, GSWAF1193D, ventral valve in ventral posterior and lateral views, ×1 F, GSWAF11193E, ventral valve in ventral view, ×1. G-H, CPC19925, ventral valve internal mould in ventral and posterior views, ×1. I-J, Q, CPC19926C, ventral valve in ventral, lateral and posterior views, ×1. K-M, CPC19927A, ventral valve in dorsal, postero-dorsal, ventral and posterior views, ×1. O-P, GSWAF11196A, ventral valve in ventral and anterior views, ×1. R-T, GSWAF11196E, dorsal valve in dorsal, postero-ventral and ventral views, ×1.2. U-V, MUGDF6029E, ventral valve in dorsal and ventral views, ×1. W-X, GSWAF11196D, ventral valve in ventral and posterior views, ×1. Y-Z, CPC19927B, ventral valve in ventral and posterior views, ×1. AA, GSWAF11196B, ventral valve in ventral view, ×1. BB, CPC19926A, ventral valve in ventral view, ×1. CC, CPC19926B, incomplete shell in dorsal view, ×1. DD, CPC19928B, natural cast of ventral valve in lateral view, ×1. EE-GG, CPC19928A, natural cast of ventral valve in ventral, posterior and lateral views, ×1.


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That this form and the two large specimens from Western Australia arc gerontic forms of *Globiella* appears inescapable as the costellae type and submature parts of the shells are typical of the species involved. The rarity of the gigantic individuals from Western Australia suggests that few specimens reached their maximum size potential and/or many large specimens were broken because the trail is extremely thin. A trail approaching that of *G. foordi* has also been figured for the Russian Kazanian species *G. hemisphaerium* (Nechaev 1911, pl. 1, figs 3b-c).

G. foordi is morphologically close to the younger *G. flexuosa* Waterhouse but can be distinguished by its smaller size at submaturity and its finer costellae. *Globiella* sp. from Bitauni, and correlated localities on the island of Timor (= *Productus cora* Broili 1916, pl. 1, figs 14, 15; pl. 2, figs 1-3; *Linoproductus cora* Shimizu 1966, pl. 16. figs 16-23) and also Letti, as discussed above, possesses costellae of similar strength to those of *G. foordi* (see Waterhouse 1970, p. 47) but can be distinguished from *G. foordi* by its clearly demarcated ears. *Globiella decemplecta* (Lu 1982, pl. 1, figs 21-23) from the Artinskian Liangshan Formation of Sichuan Province, China is close to *G. foordi* with respect to its shell shape and ventral convexity. Costellae of the Chinese species are a little finer than those of *G. foordi*. *Linoproductus* cf. *foordi* (Yang & Ting 1962, pl. 24, fig. 5a, b) from the Early Permian of the Chi Lien Mountains, China, known from a single, moderately globular shell has fine costellae but its precise affinities are not clear.

G. umariensis is spinose and has costellae finer than those of *G. foordi*. *Globiella* sp. of Acharyya *et al.* (1975, pl. 2, fig. G) appears even more spinose than *G. umariensis*. The poorly known *G. gracilis* (Ching *et al.* 1977) also possesses fine costellae and appears to be less globular and ventrally convex than *G. foordi*.

G. rossiae (Fantini Sestini 1966) is less convex ventrally also has finer costellae than *G. foordi*. Kazanian *Globiella* from the Russian Platform and the Arctic possess costellae much finer than the Gondwanan species outlined above (Waterhouse 1970, Grigor'eva *et al.* 1977). They form a distinct, compact group of *Globiella* species that may well be generically distinct from Gondwanan species referred to the genus on details of ornament and trail.

Globiella flexuosa (Waterhouse 1970)

Fig. 40-Z, AA-BB

1970 *Stepanoviella flexuosa* Waterhouse, p. 45, pl. 14, figs 1-8, 15-16.

1971 *Stepanoviella flexuosa* Waterhouse. *Proc. Pap. 2nd Gondwana Symp.* p. 391.

Holotype: CPC8661 (Waterhouse 1970, pl. 14, fig. 2) an incomplete ventral valve from the Jimba Jimba Calcarenite, Carnarvon Basin.

Material and Locality: MUGDF6030A-N, 14 ventral valves from G. A. Thomas locality W758, type section of Jimba Jimba Calcarenite (Lat. 25°02.75'S, Long. 114°58.8E) Jimba Jimba Station, 15 km west of Jimba Jimba Homestead. Aktastinian (Early Artinskian).

Diagnosis: Medium sized *Globiella*, often transverse in outline. Ornament of distinct radial costellae, coarse for genus.

Table 7
Measurements of *Globiella flexuosa* (Waterhouse 1970) in mm. e = estimate; † = incomplete specimen

Specimen number (all MUGD)	Hinge width	Maximum width	Ventral length	Thickness
6030A	26.5	33.0	–	14.0†
6030B	28.8	33.5	31.2	19.0e
6030C	29.0†	33.0	26.0†	–
6030D	–	31.0	28.5	15.0
6030E	–	29.0†	24.8	–
6030F	24.0	26.0	27.2	14.9
6030G	–	27.0†	25.4†	–
6030H	–	28.0	25.6	–

Description: Shell outline transverse to subquadrate and subcircular. Ventral valve strongly convex, globular. Maximum shell width at hinge line from youth into maturity but moves to about mid-length in old age. Umbo small, low, pointed and overhangs hinge line. Ears small, blunt and slightly twisted ventrally; poorly demarcated from remainder of valve. No distinct flattening or sulcus in ventral valve; valve evenly convex although some specimens are slightly less convex medianly. No complete trail has been observed although one specimen, MUGDF6030B, indicates the presence of a trail. Hinge line straight, carries row of ventral hinge spines larger towards ears and at low angle to hinge and point away from umbo. Spines absent over body of ventral valve. Moderately distinct rugae developed over ears and lateral flanks of ventral valve and, at times, extend over visceral disc. Ventral ornament consists of radial, rounded costellae, increasing usually by intercalation; at times sinuous and increasing by bifurcation. Costellae, separated by wide interspaces, are relatively coarse (12-14 per cm at 1 cm from umbo and 10-12 per cm from umbo), the available collection suggesting that no specimens have costellae any finer. Ventral valve thin anteriorly but thickened posteriorly along hinge and adjacent to muscle scars. Muscle marks deep; adductor scars posteriorly located, elongate, lobate and smooth or anteriorly grooved. Diductor scars large, broadly oval and distinctly ridged and grooved.

Dorsal valve concave with small ears. Dorsal external ornament of fine concentric wrinkles or rugae crossing visceral disc and distinct costellae that increase by bifurcation. Costellae of comparable size to those of ventral valve judging from sole available specimen. No dorsal spines. Dorsal interior unknown.

Discussion: The species is close to *G. foordi* but may be distinguished from Etheridge's species by its generally larger size at submaturity, often more pronounced ven-

tral rugae and consistently coarser costellae. The coarseness of the costellae of *G. flexuosa* sets the species apart from all other known species of the genus.

Specimens from the Early Permian of Afghanistan compared with *G. flexuosa* by Termier and Termier (1971) have not been fully described. *Stepanoviella flexuosa* of Jing and Sun (1981, p. 140, pl. 5, figs 7-8) from the Qinghai-Xizang Plateau possesses coarse costellae like the Western Australian species and although known from limited material, appears closely allied to *G. flexuosa*.

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